Photoproduction of η/π^0 on the deuteron at 1 GeV

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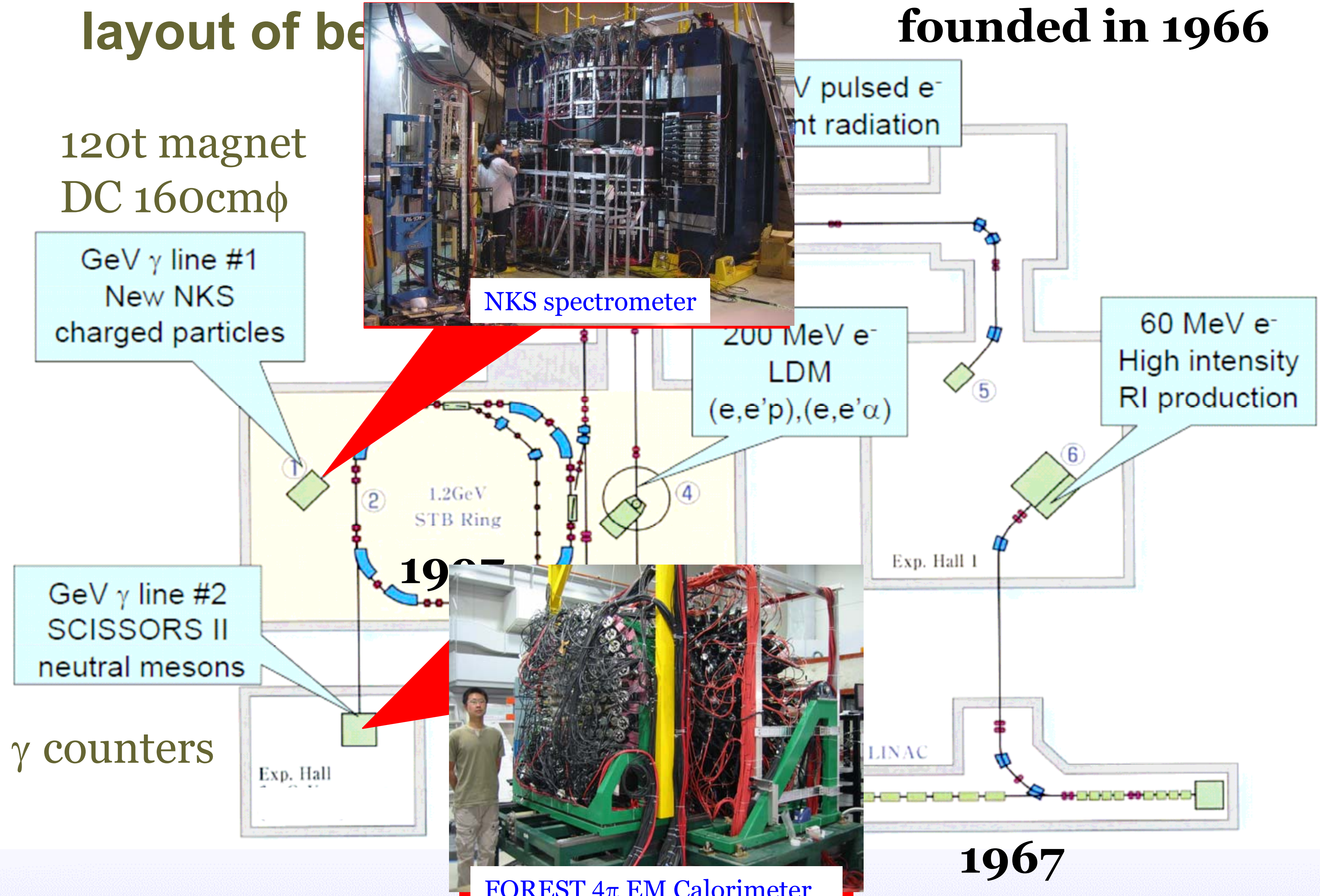
GeV γ experiments at Laboratory of Nuclear Science (LNS)

layout of be **founded in 1966**

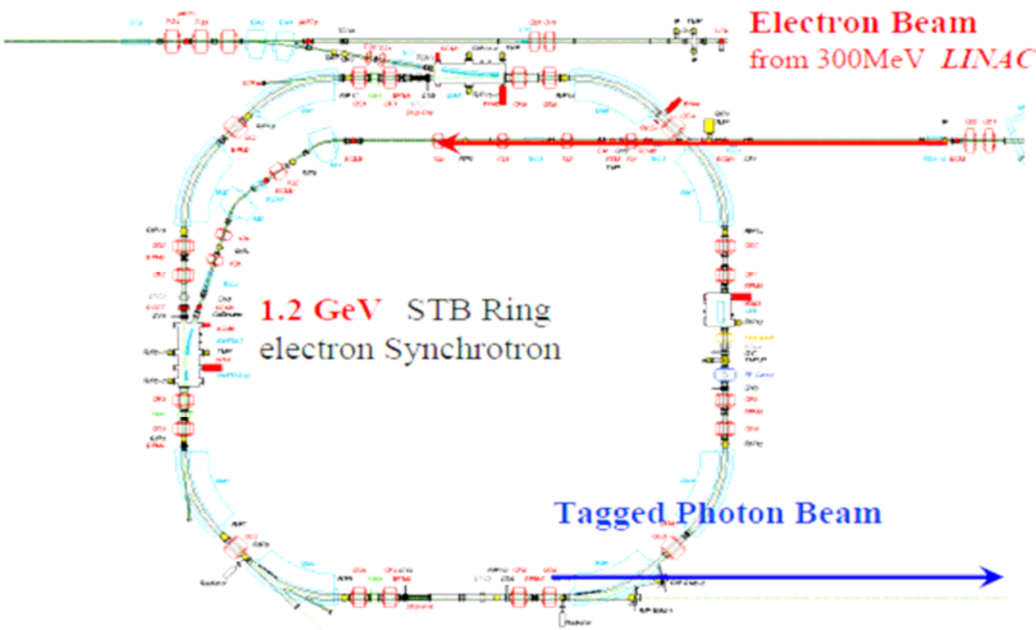
120t magnet
DC 160cmϕ



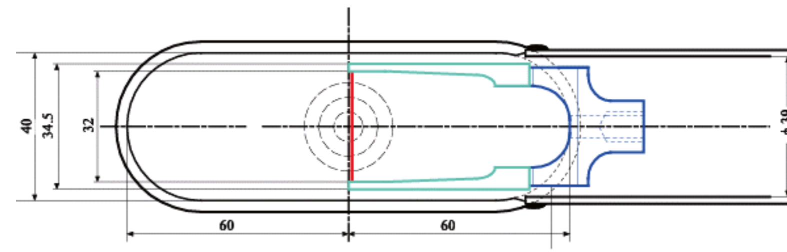
γ counters

1967

GeV γ experiments at LNS

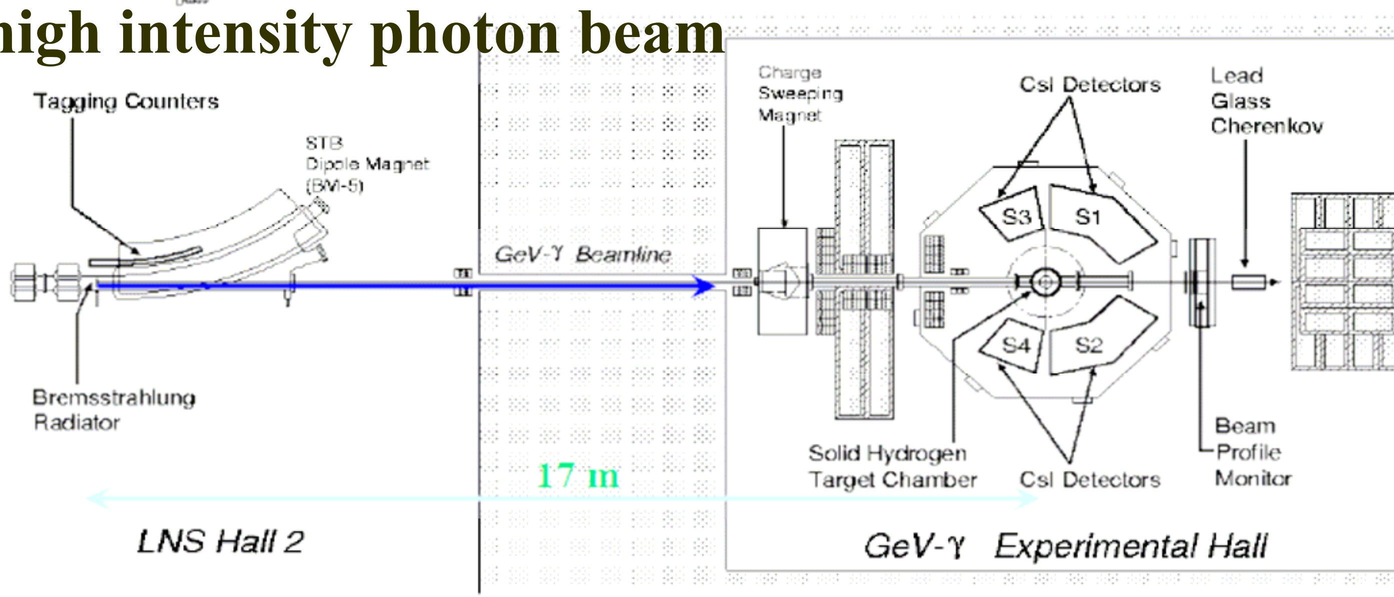


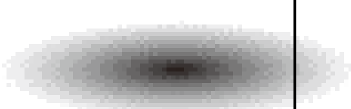
internal radiator



carbon fiber 11μmφ

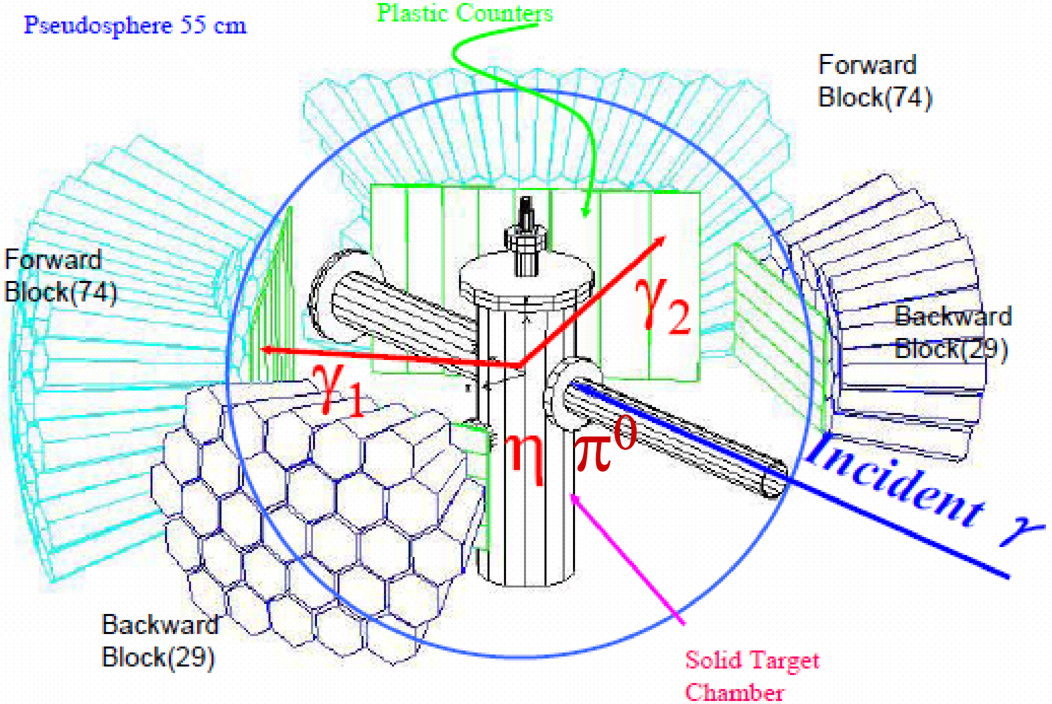
very high intensity photon beam





Experimental setup

$SCISSORS\ II$:206 pure CsI Crystals
(1.57 str = 12.5% of 4 π)
16.2 X_0 for Forward 148 crystals
13.5 X_0 for Backward 58 crystals



Hydrogen/Deuterium
Solid Target
t = 8 cm (N_T ~4 × 10^{23}/cm^2)

$$\gamma + N \rightarrow \eta + X$$

Identification of η meson
$\Gamma_{\eta-\gamma\gamma}$ **= (39.43±0.26)%**
→ γγ Decay Channel

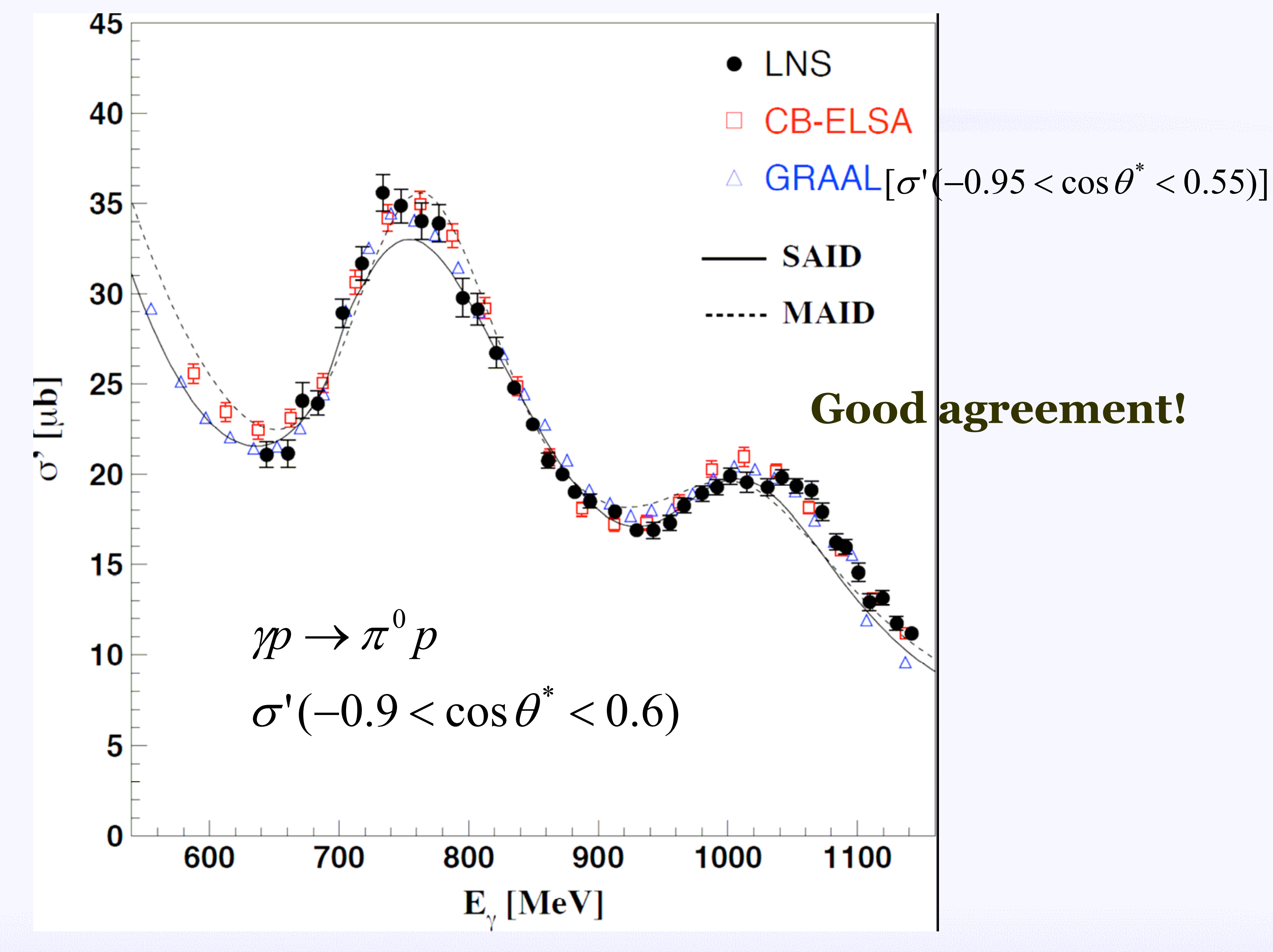
$$\gamma + N \rightarrow \pi^0 + X$$

⇓

γγ Invariant Mass Analysis

$$M_{\gamma\gamma}^2 = 2E_{\gamma_1}E_{\gamma_2}(1 - \cos\Phi_{\gamma\gamma})$$

Energy :$E = \Sigma E_i$
Position :$R = \Sigma R_i E_i / \Sigma E_i$



LNS
CB-ELSA
GRAAL
$[\sigma'(-0.95 < \cos\theta^* < 0.55)]$
SAID
MAID
Good agreement!
$\gamma p \to \pi^0 p$
$\sigma'(-0.9 < \cos\theta^* < 0.6)$
σ' [μb]
E$_\gamma$ [MeV]

Discussion and Questions

- Can the familiar physics account for the structure observed in $\gamma n \to \eta n$?
- Do we have any reasons to expect narrow non-strange baryonic states having non-exotic nature?
- Could we consider any other reactions to look for such a narrow non-strange baryon?
- Do we need exotica?
- ....
- ....

Experimentally:
Look into the neutron channel!
(neutron data: not well-established)

Dying for a convenient tool

(like SAID and MAID)

- to analyze data for meson production on the DEUTERON
- to analyze data at least for the QF process
- to extract neutron information

despite many theoretical works reproducing deuteron data to a certain degree.

Disagreement between theoretical and experimental results is still open question for $\gamma d \to \pi^0 np$ in the 2nd resonance region.

Angular distributions

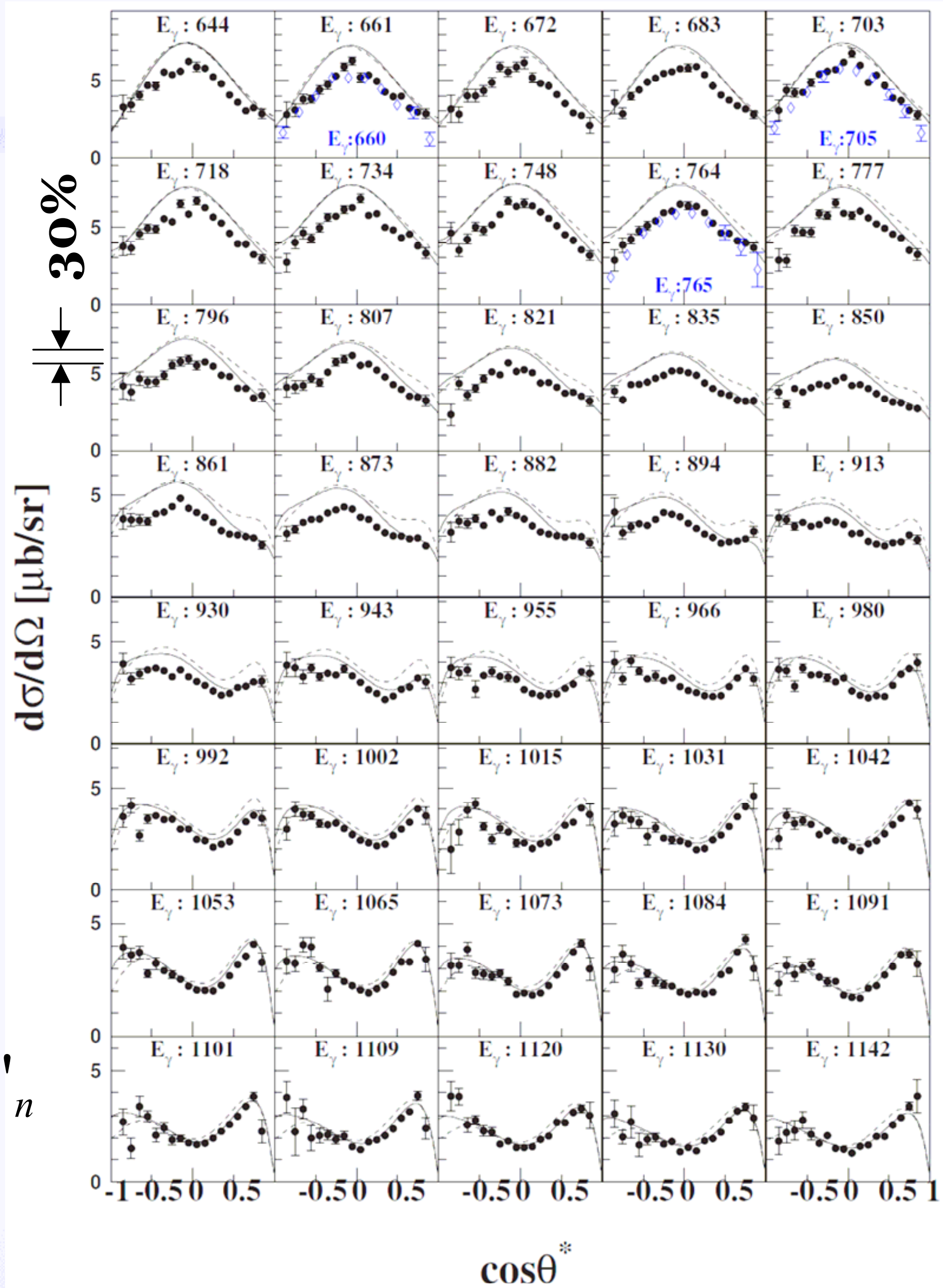
$$d\sigma / d\Omega(\gamma d \rightarrow \pi^0 np)$$

in the $\pi^0 N$ CM system under QF condition:

$$\gamma N' \rightarrow \pi^0 N$$

- **new data**
- **Mainz**
- **SAID**
- **MAID**

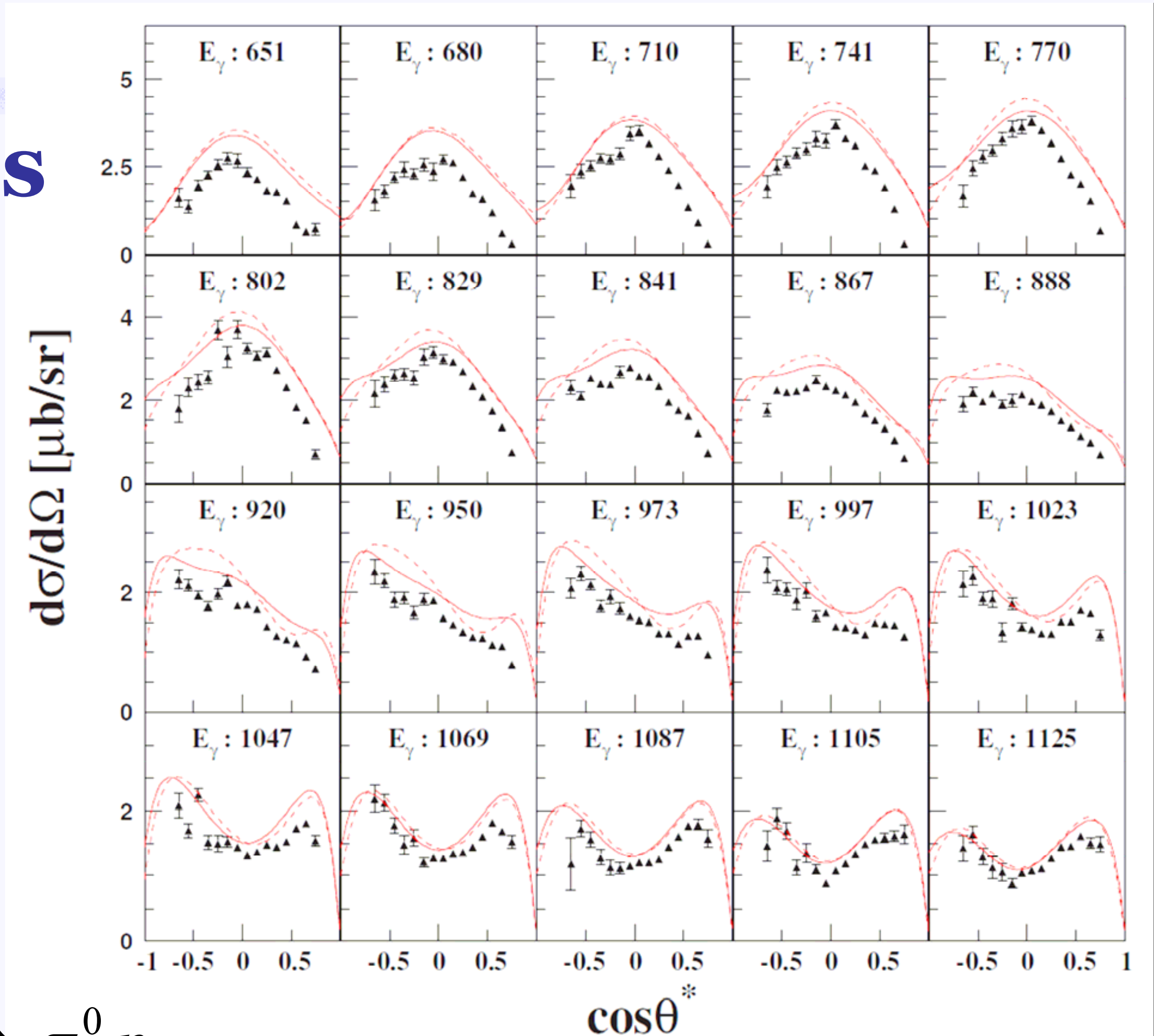
$$\sigma'_p + \sigma'_n$$



Angular distributions

$$d\sigma / d\Omega(\gamma N' \rightarrow \pi^0 p)$$

with detection of a charged particle



▲ **our data**

—— **SAID**

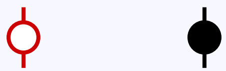
$$\gamma p' \rightarrow \pi^0 p$$

- - - - **MAID**

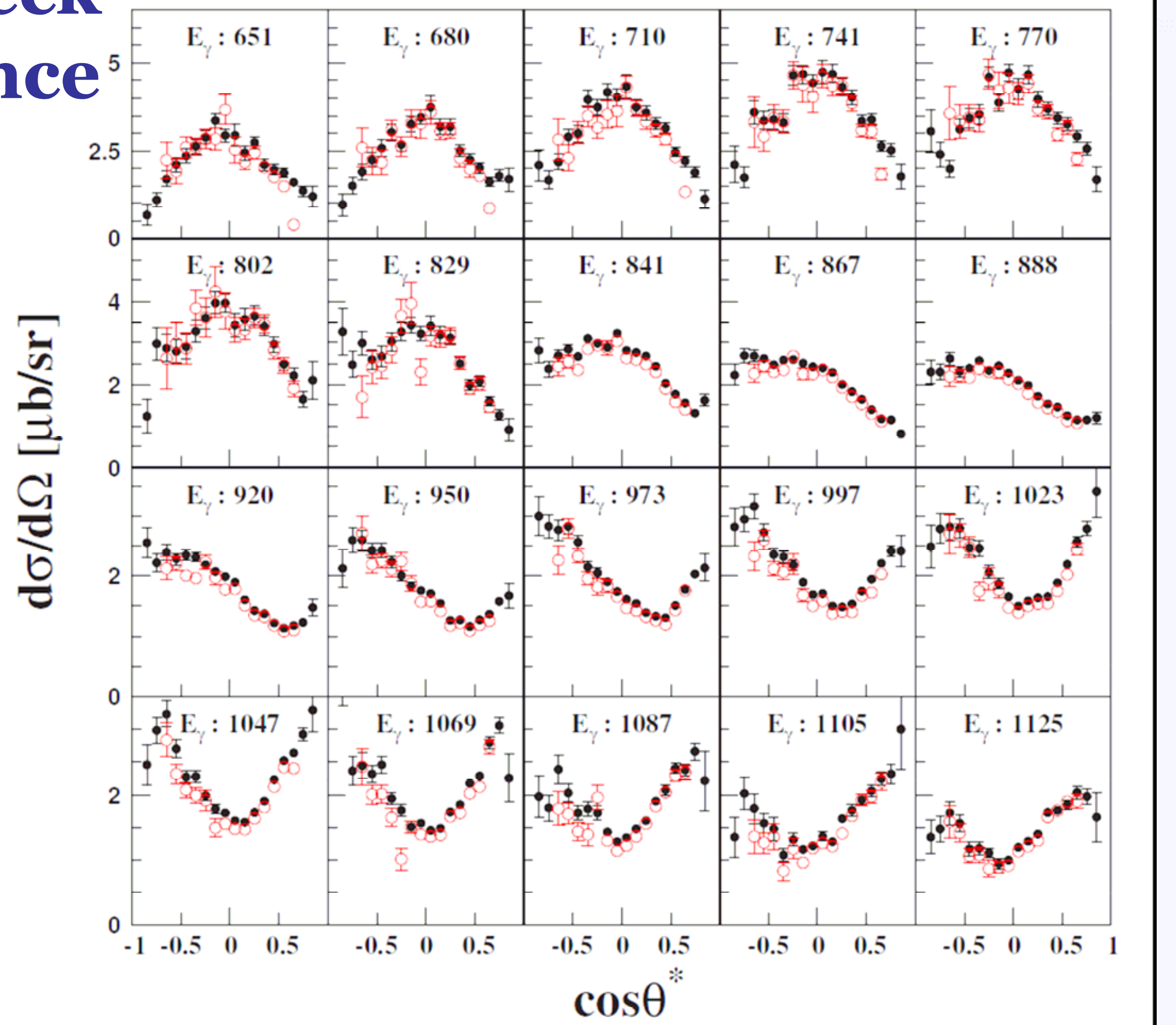
Need to check the acceptance!

$$d\sigma / d\Omega(\gamma p \rightarrow \pi^0 p)$$

Consistency check for the acceptance with a proton target

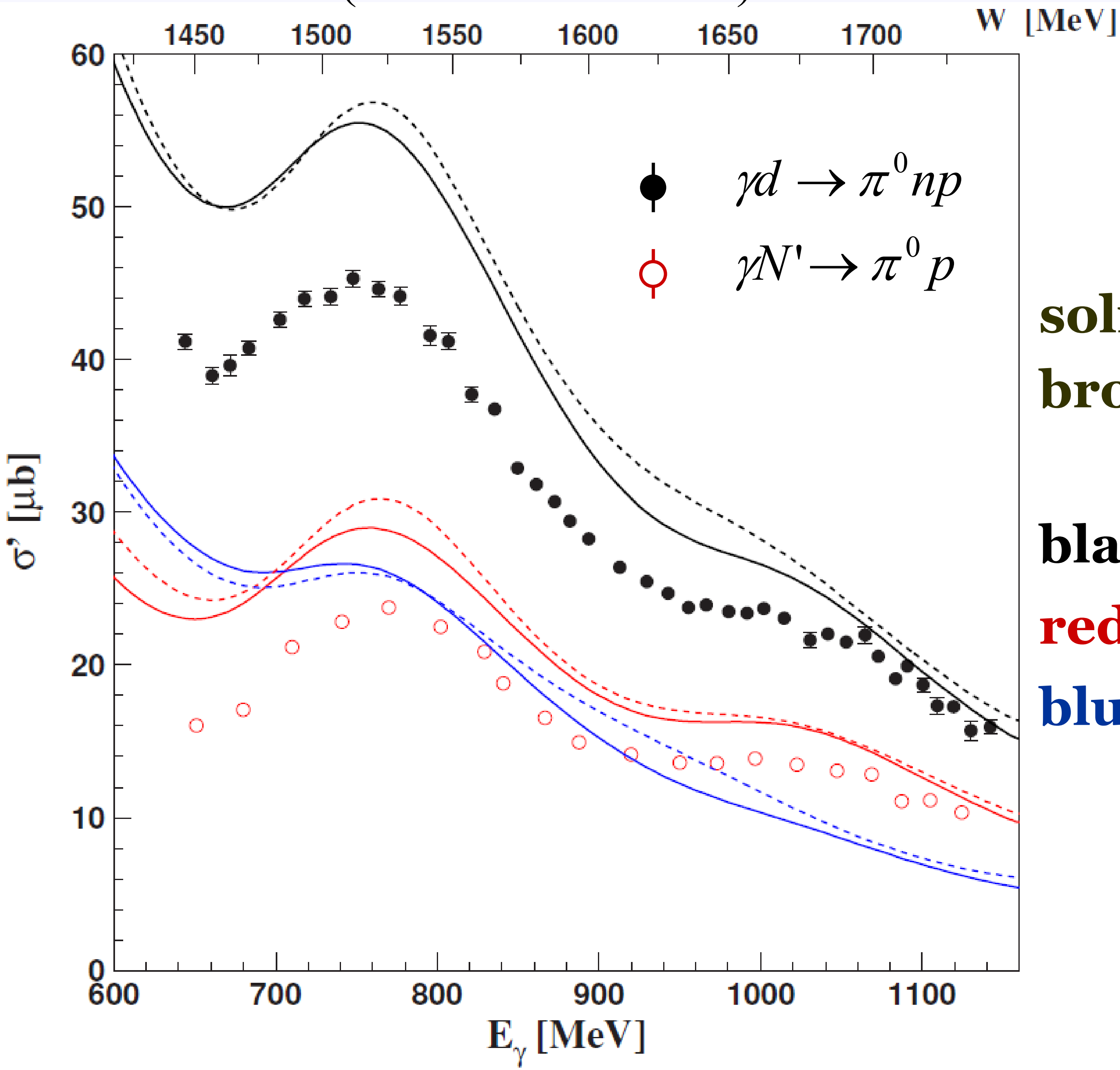


with (without) detection of an additional charged particle



Good agreement between data

$\sigma'(-0.7 < \cos\theta^* < 0.6)$



solid lines: SAID

broken : MAID

black: $\sigma'_p + \sigma'_n$

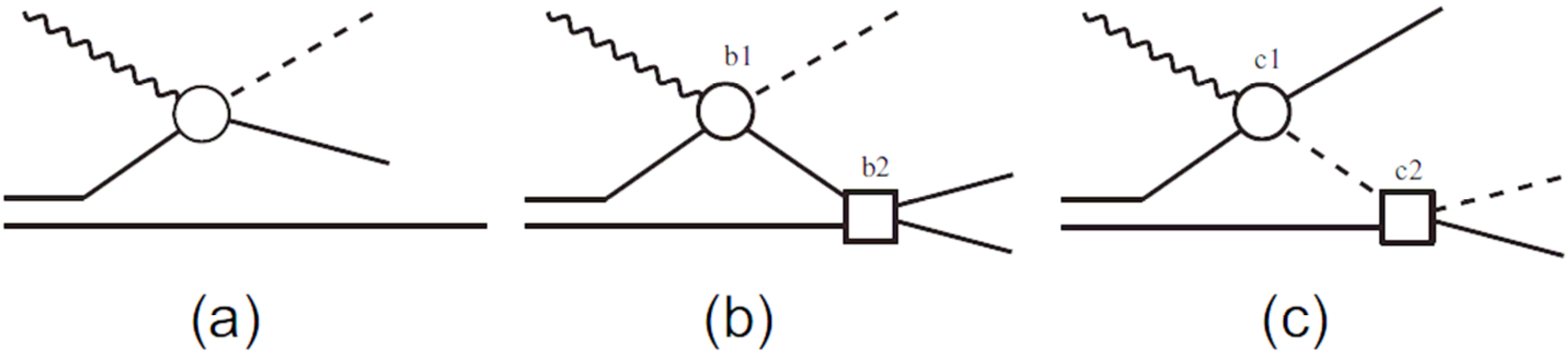
red : σ'_p

blue : σ'_n

Wanted a tool!

Effects of FSI in the QF process

$$\gamma d \to \pi^0 np$$

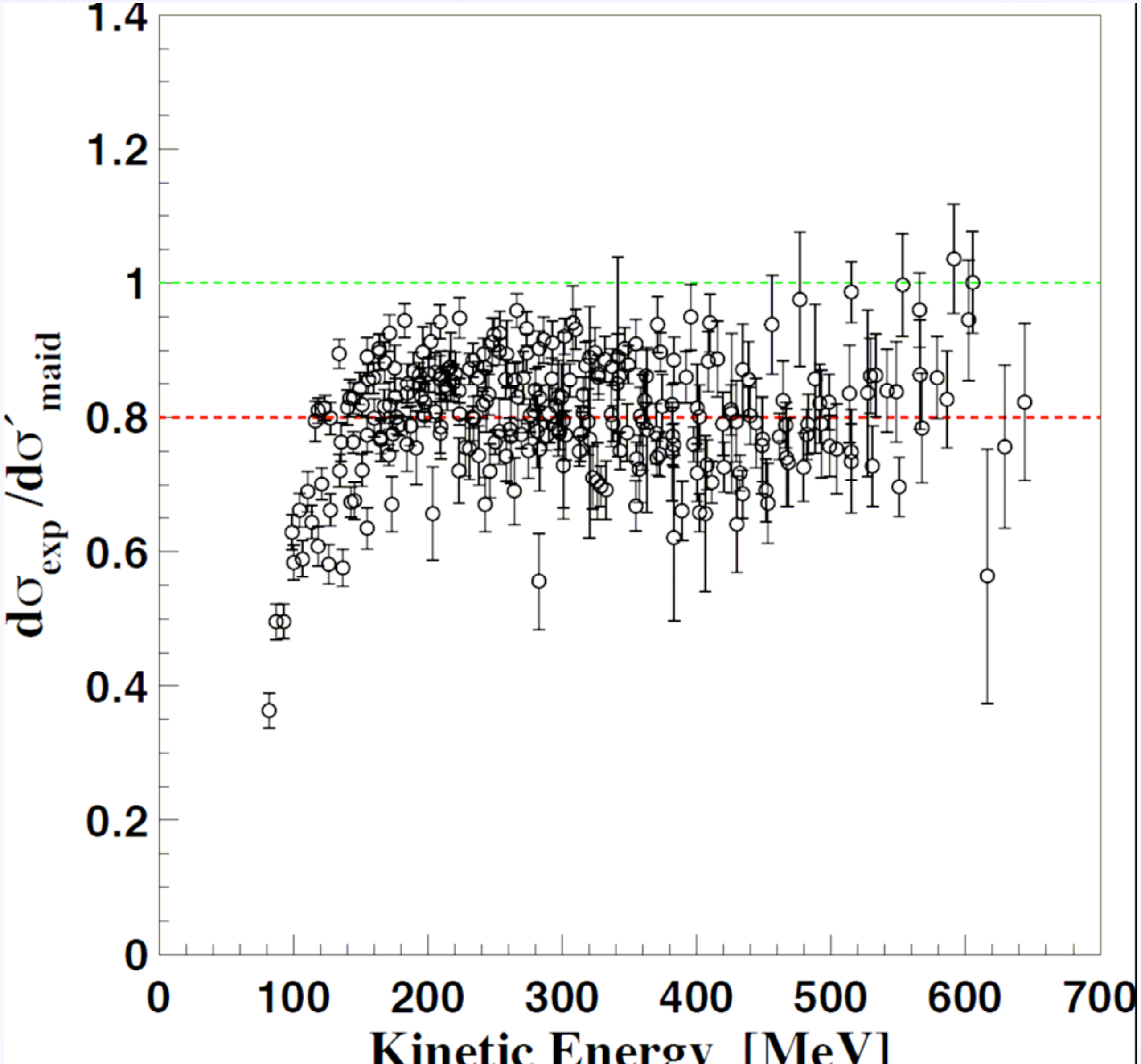


$$\frac{d\sigma}{d\Omega}(\gamma d \to \pi^0 np) \propto \left| T_{\pi p} + T_{\pi p}T_{pn} + T_{\pi n}T_{np} \right|^2 \qquad \gamma N' \to \pi^0 p$$

$$+ \left| T_{\pi n} + T_{\pi n}T_{np} + T_{\pi p}T_{pn} \right|^2 \qquad \gamma N' \to \pi^0 n$$

N-N FSI plays an important role.

Reduction factor α



$$\frac{\dfrac{d\sigma}{d\Omega}(\gamma N' \rightarrow \pi^0 p)\,\exp}{\dfrac{d\sigma}{d\Omega}(\gamma p' \rightarrow \pi^0 p) MAID}$$

$$E_\gamma > 640 MeV$$

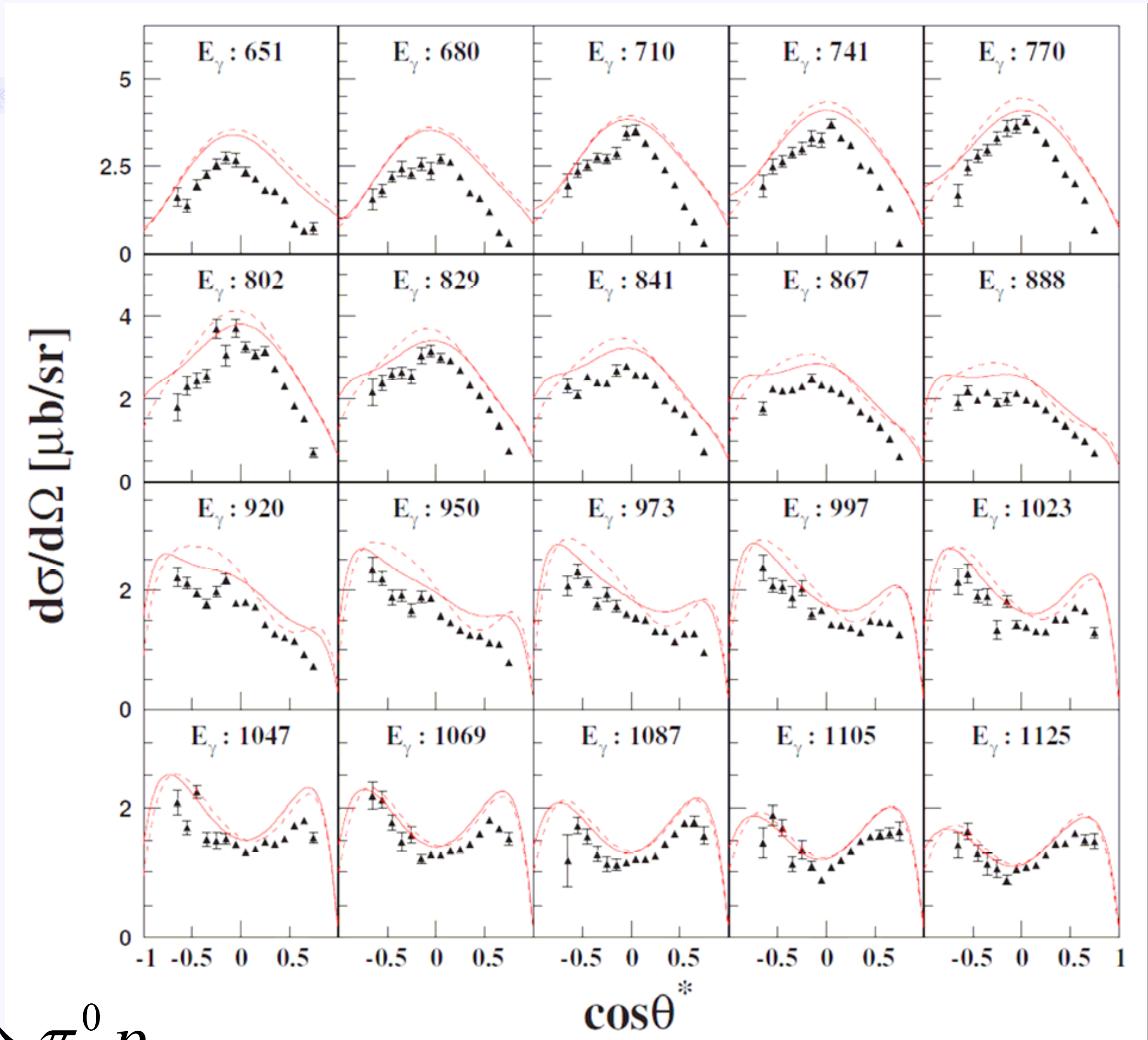
$$-0.7 < \cos\theta^* < 0.6$$

$$\alpha = 0.8$$

Angular distribution

$$d\sigma / d\Omega(\gamma N' \to \pi^0 p)$$

with detection of a charged particle



▲ **our data**

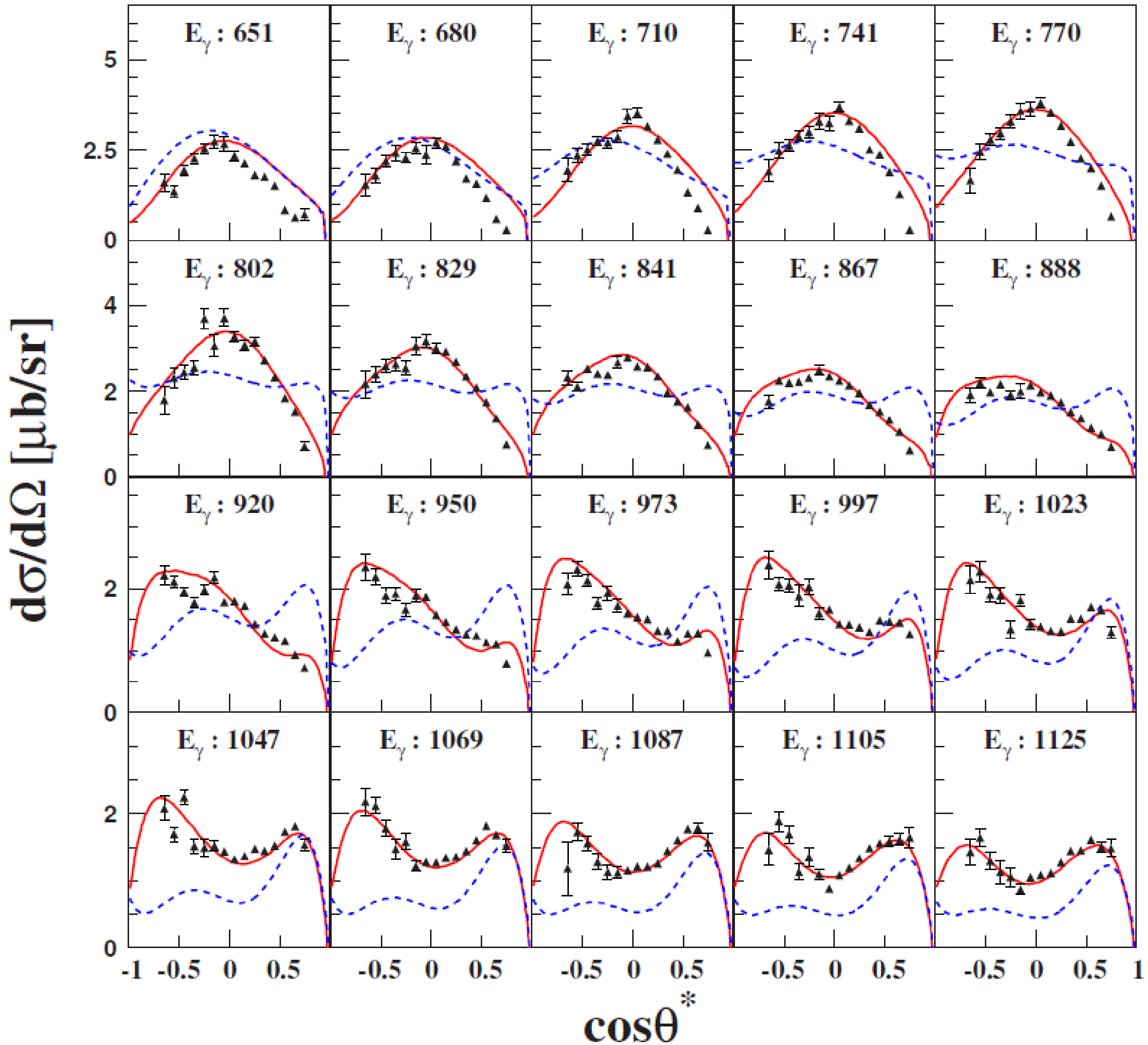
—— **SAID**

$$\gamma p' \to \pi^0 p$$

- - - - **MAID**

Angular distribution

$d\sigma / d\Omega(\gamma N' \rightarrow \pi^0 p)$

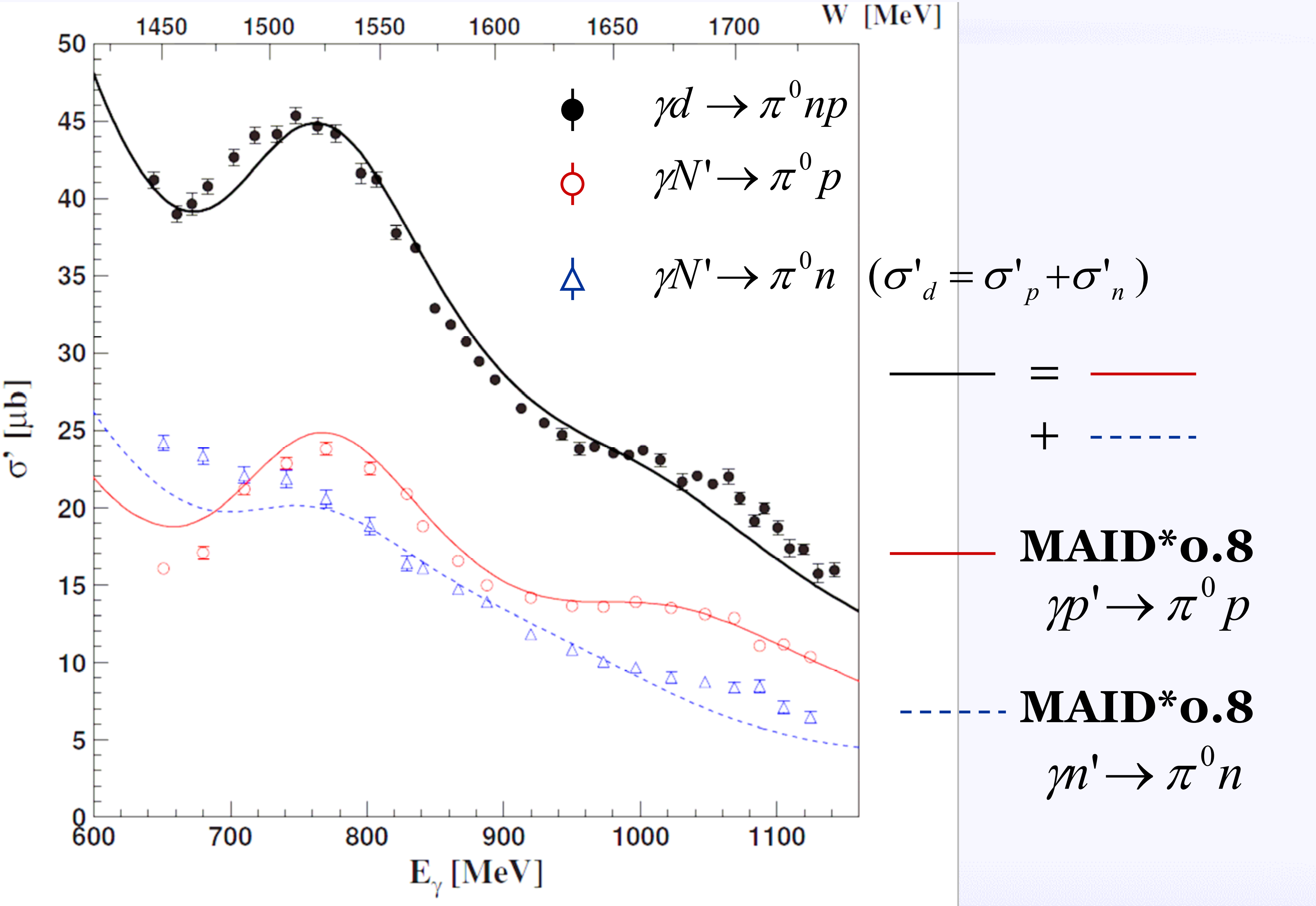


▲ **our data**

MAID*0.8 $\gamma p' \rightarrow \pi^0 p$

MAID*0.8 $\gamma n' \rightarrow \pi^0 n$

$\sigma'(-0.7 < \cos\theta^* < 0.6)$



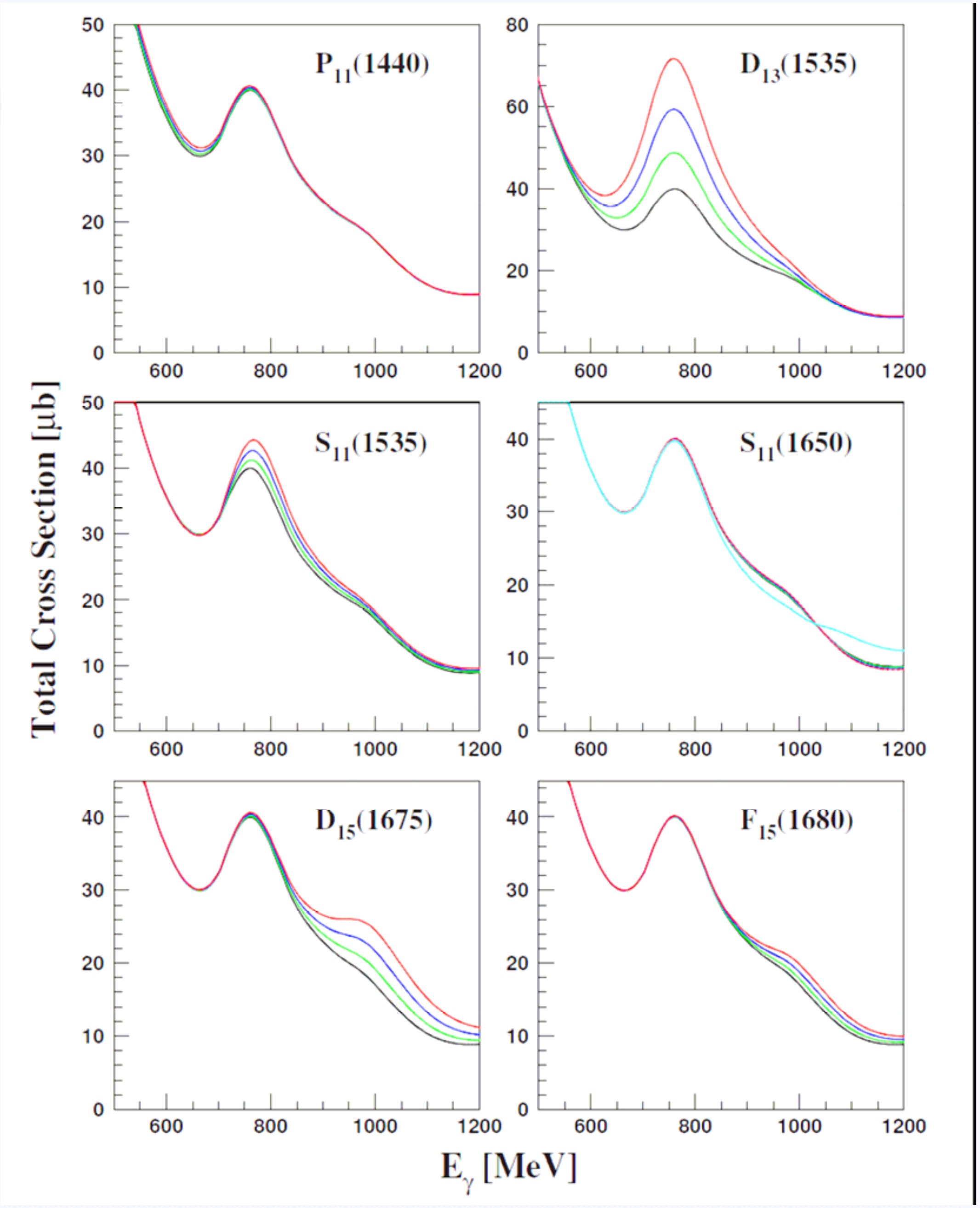
Effects of the change of helicity amplitudes on each resonance

$A^n \times 1.2$ (green)

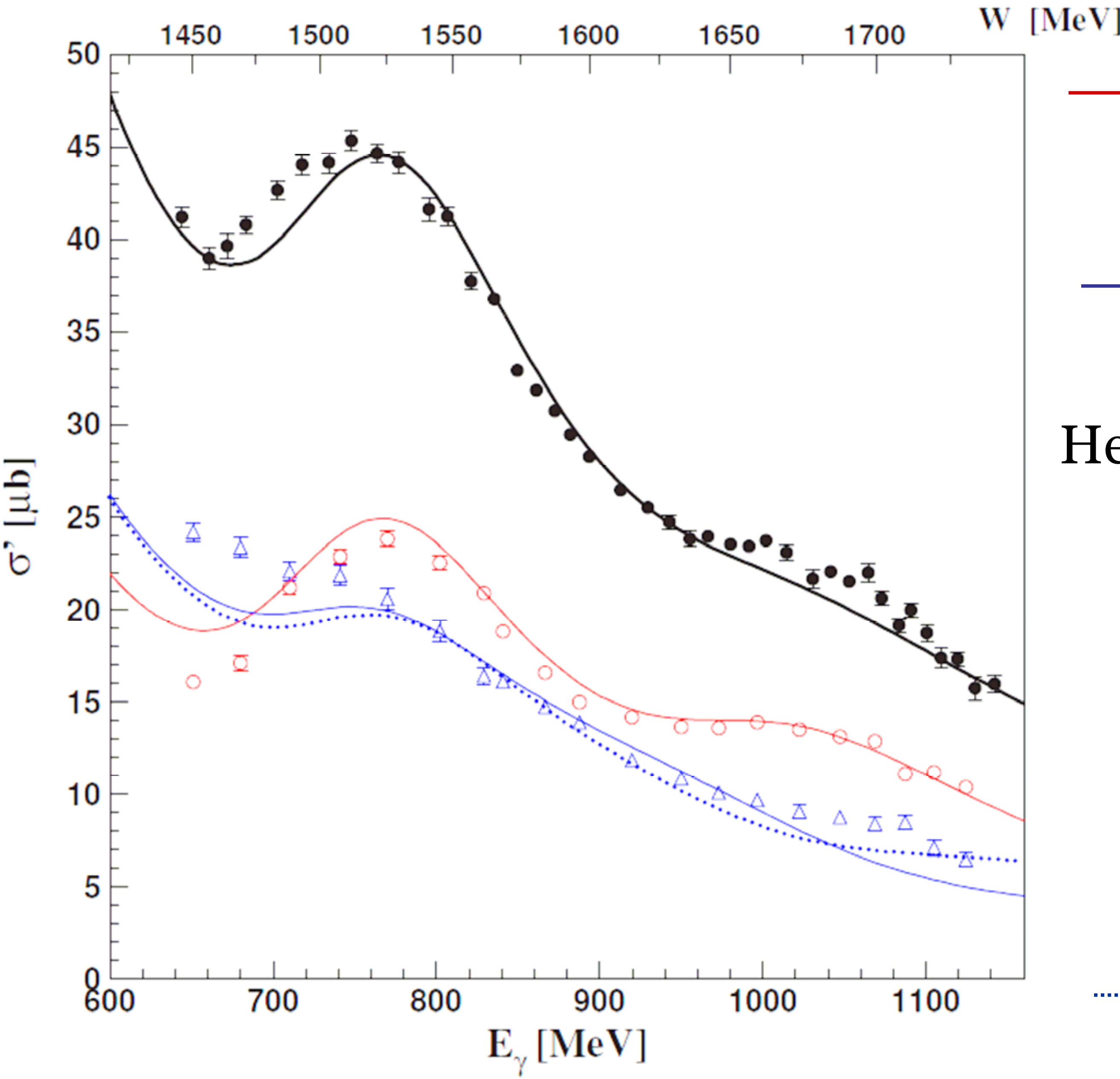
$\times 1.4$ (blue)

$\times 1.6$ (red)

$\times -1.6$ (light blue)



$$\sigma'(-0.7 < \cos\theta^* < 0.6)$$



MAID*0.8

$\gamma p' \to \pi^0 p$

MAID*0.8

$\gamma n' \to \pi^0 n$

Helicity amplitudes

$A^n_{1/2}$ $A^n_{3/2}$

$D_{13}(1520)$

$S_{11}(1535)$

$S_{11}(1650)$

$D_{15}(1675)$

$F_{15}(1680)$

$P_{13}(1720)$

Fitted

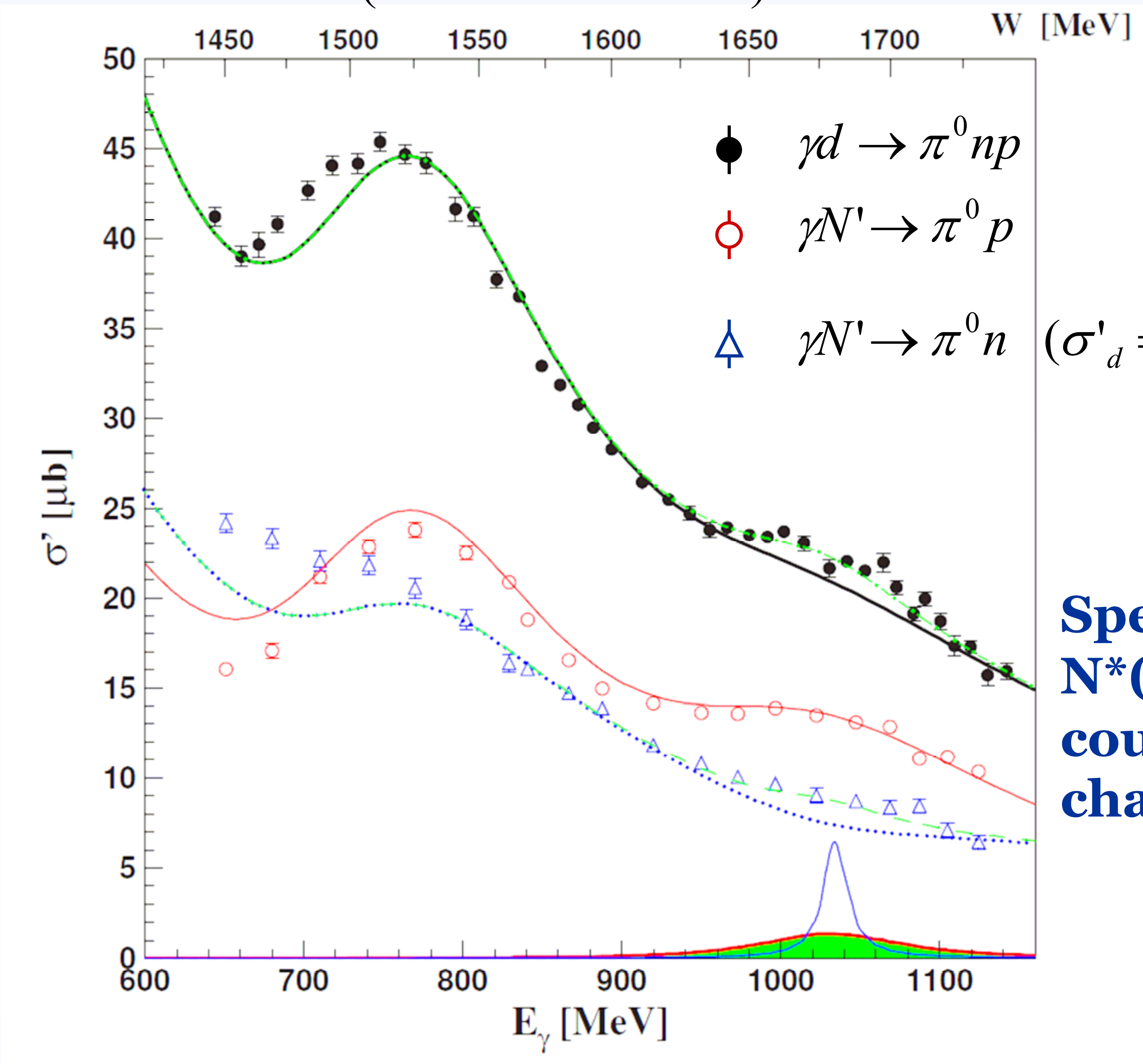
Helicity amplitudes in the neutron channel

	$A^n_{1/2}$			$A^n_{3/2}$		
	PDG	**MD07**	**Fit**	**PDG**	**MD07**	**Fit**
D_{13}(1520)	–59±9	–76.53	–74.8	–139±11	–154.1	–147.1
S_{11}(1535)	–46±27	–50.67	–67.5			
S_{11}(1650)	–15±21	+9.25	–20.8			
D_{15}(1675)	–43±12	–61.74	–63.9	–58±13	–83.87	–57.3
F_{15}(1680)	+29±10	+27.89	+21.0	–33±9	–38.38	–47.4
P_{13}(1720)	+1±15	–5.4	–3.0	–29±61	–30.97	–17.5

$[\times 10^{-3}\, GeV^{-1/2}]$

Fit was made within the error range of PDG values.

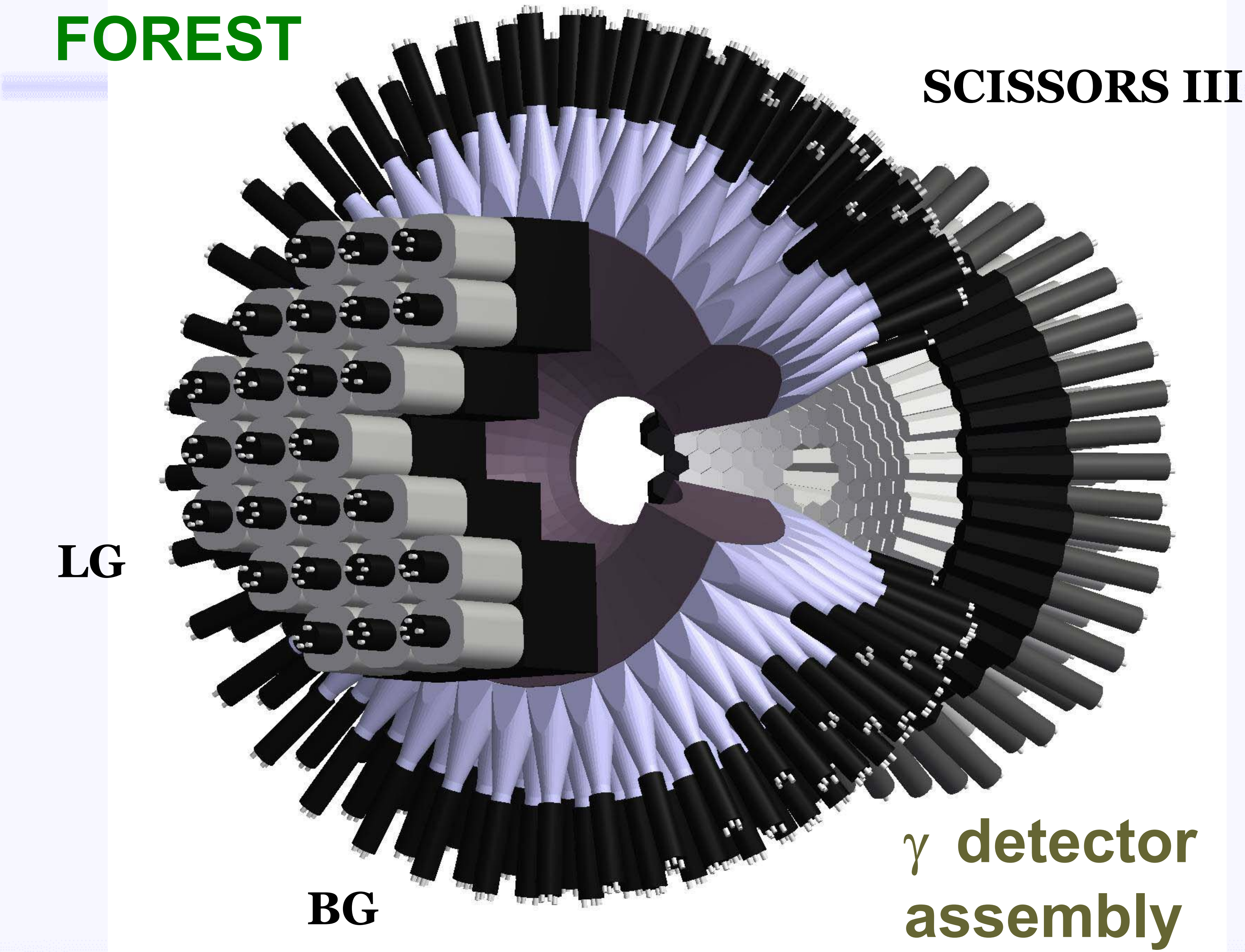
$\sigma'(-0.7 < \cos\theta^* < 0.6)$



Speculation: N*(1680) might couple to $\pi^0 n$ channel?

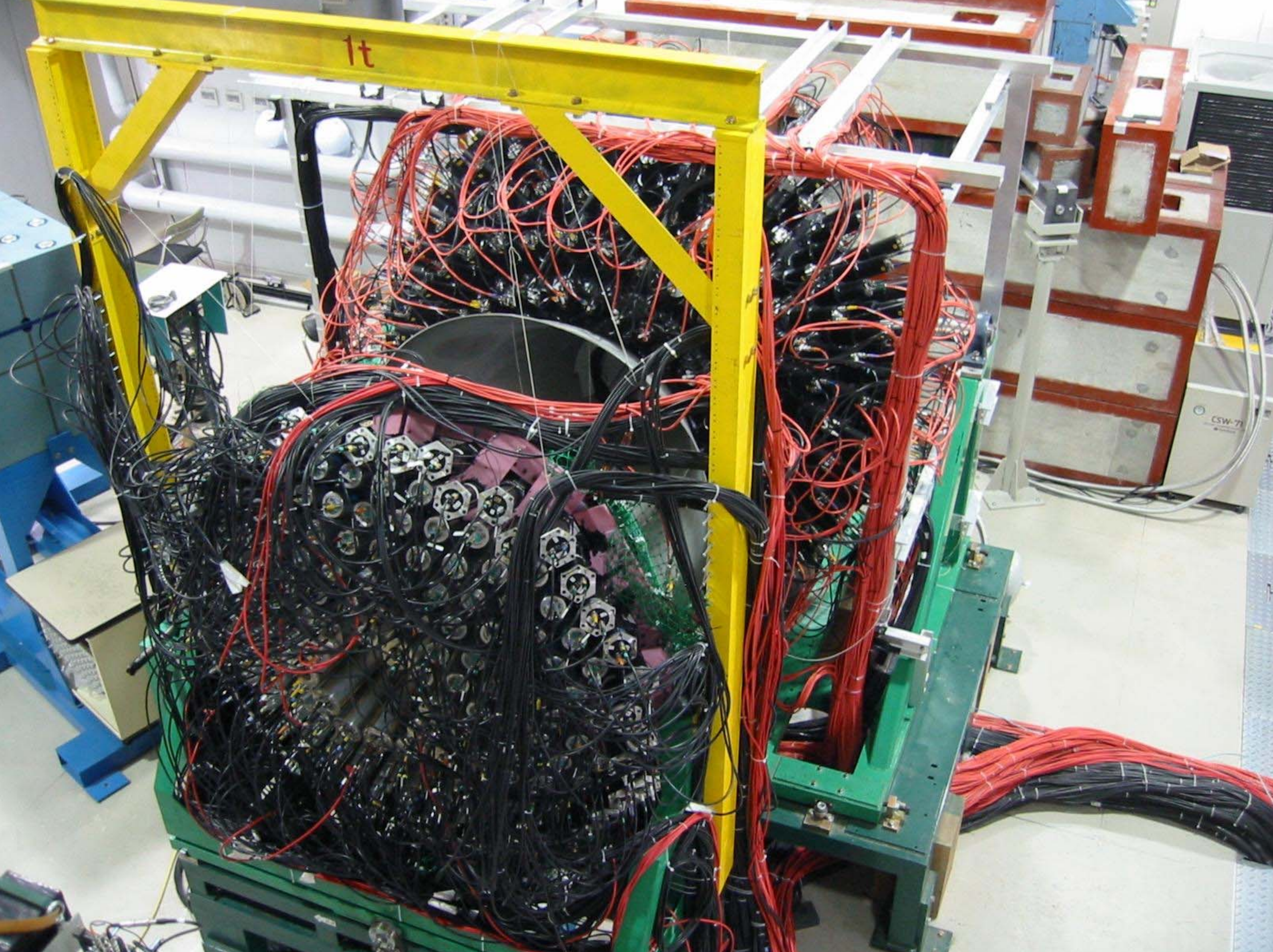
Summary of the present experiment

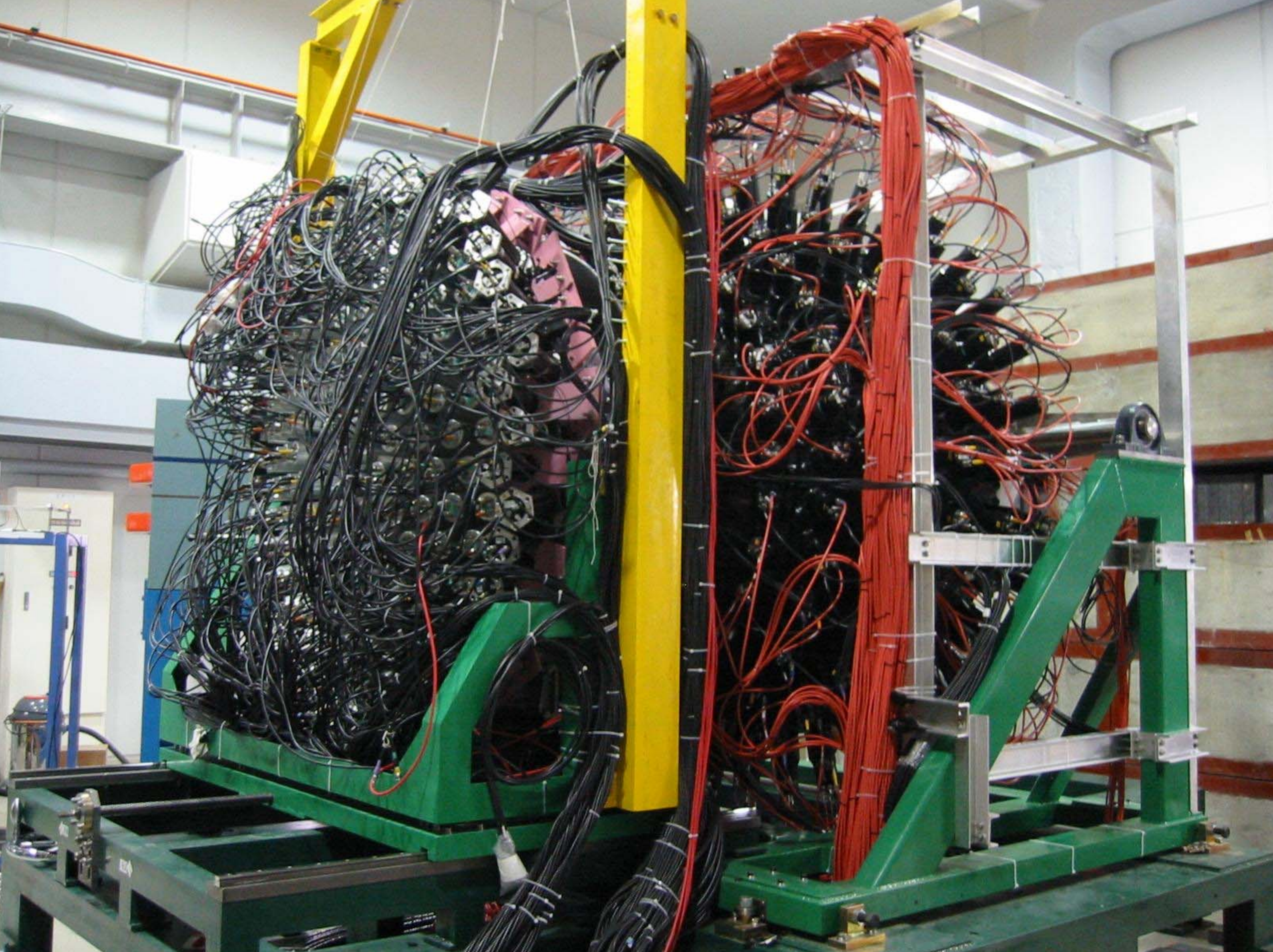
- $d\sigma / d\Omega(\gamma d \to \pi^0 np)$ **has been measured.**
  $(-0.9 < \cos\theta^* < 0.9)$ **New data for** $E_\gamma > 800 MeV$**.**
- **MAID and SAID overestimate the data by about 30% at the 2nd resonance region.**
  The discrepancy gradually gets smaller and looks disappear at $E_\gamma > 1 GeV$ **.**
- **Good agreement at 1 GeV is kind of illusion due to poor information on the neutron channel.**
  Cuz MAID and SAID predictions exceed data of semi-exclusive $\gamma N' \to \pi^0 p$ **even at** $E_\gamma > 1 GeV$**.**
- **A rough estimation of the data indicates a possibility that N*(1680) might couple to the** $\pi^0 n$ **channel.**


FOREST
SCISSORS III
LG
BG
γ detector assembly

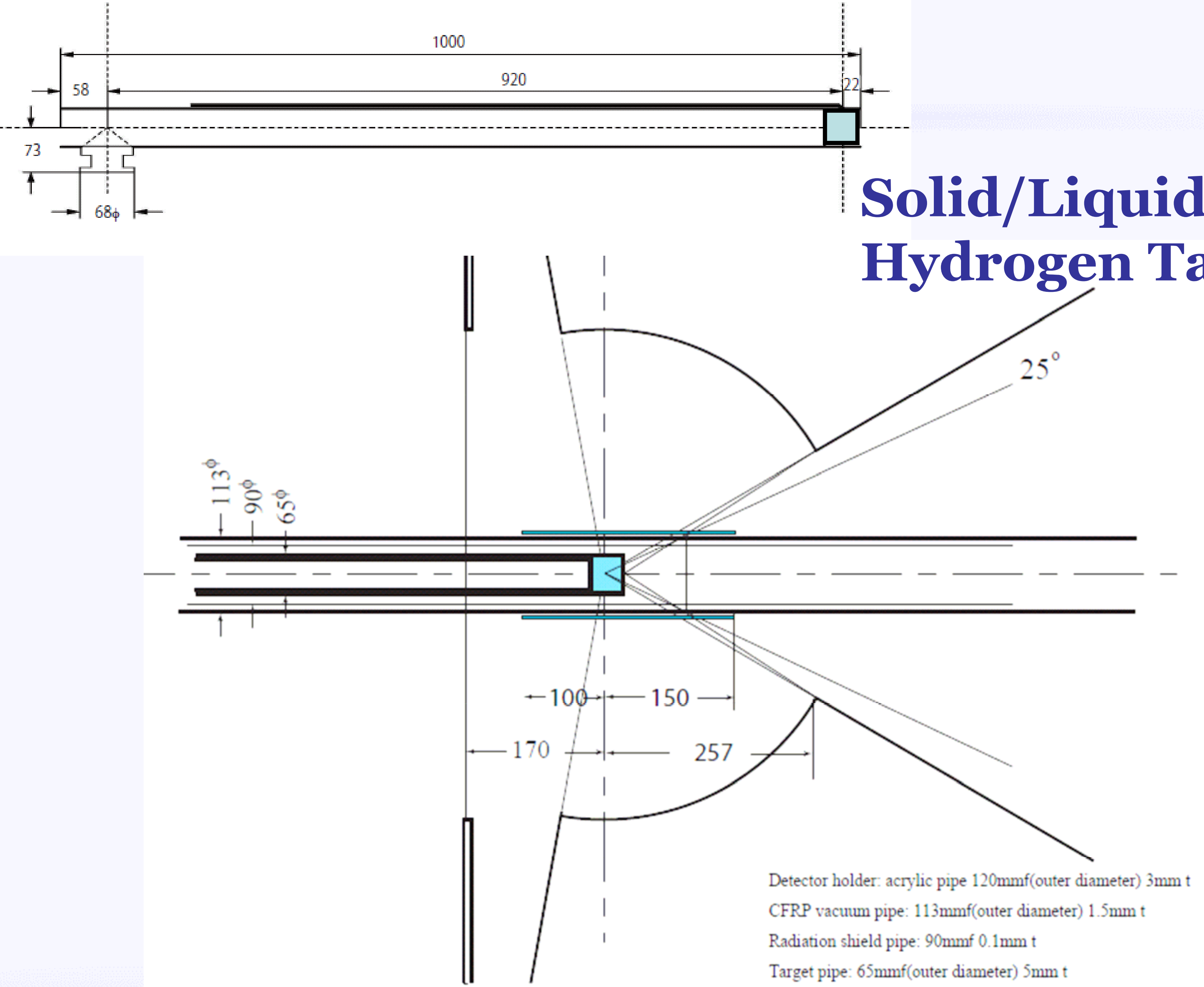

7.5 TON

SCISSORS III


1t



Solid/Liquid Hydrogen Target



Solid/Liquid Hydrogen Target

- feeding pipe (4N pure Al)
  cooled by a GM cooling system

length:	1000 mm

- target cell
  cooled down to 4.7 K

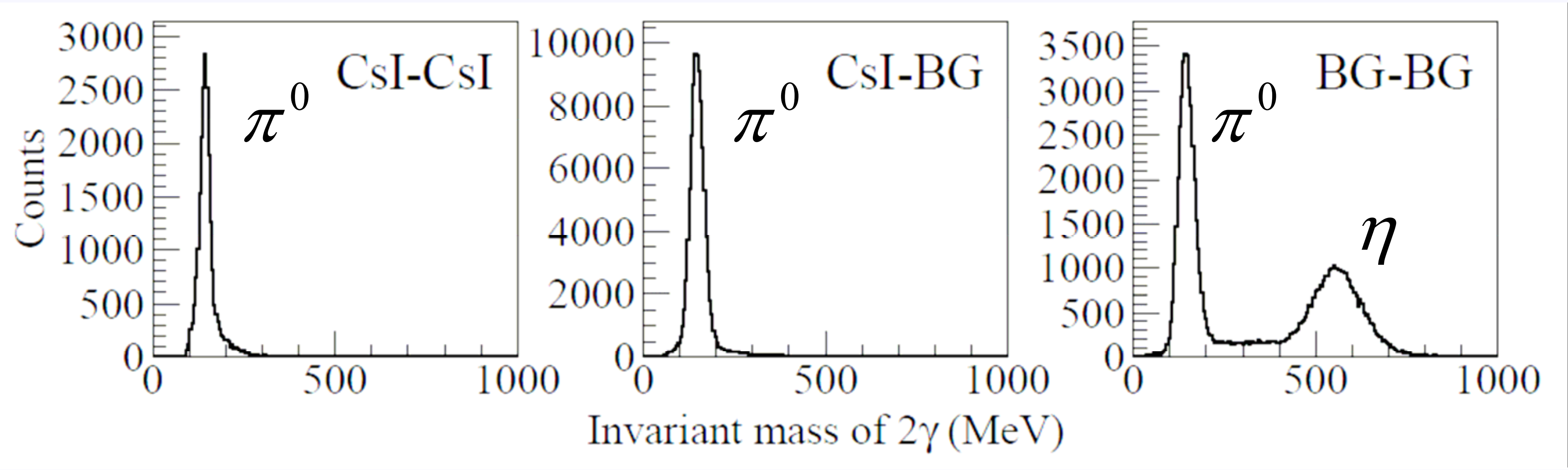
target thickness:	40 mm
inner diameter:	61 mm
outer diameter:	65 mm
window (Aramid):	12.5 μm x 2

- operation

pre-cooling:	3 hours
target making:	2 hours
target vaporizing:	1 hour

2γ invariant mass distributions

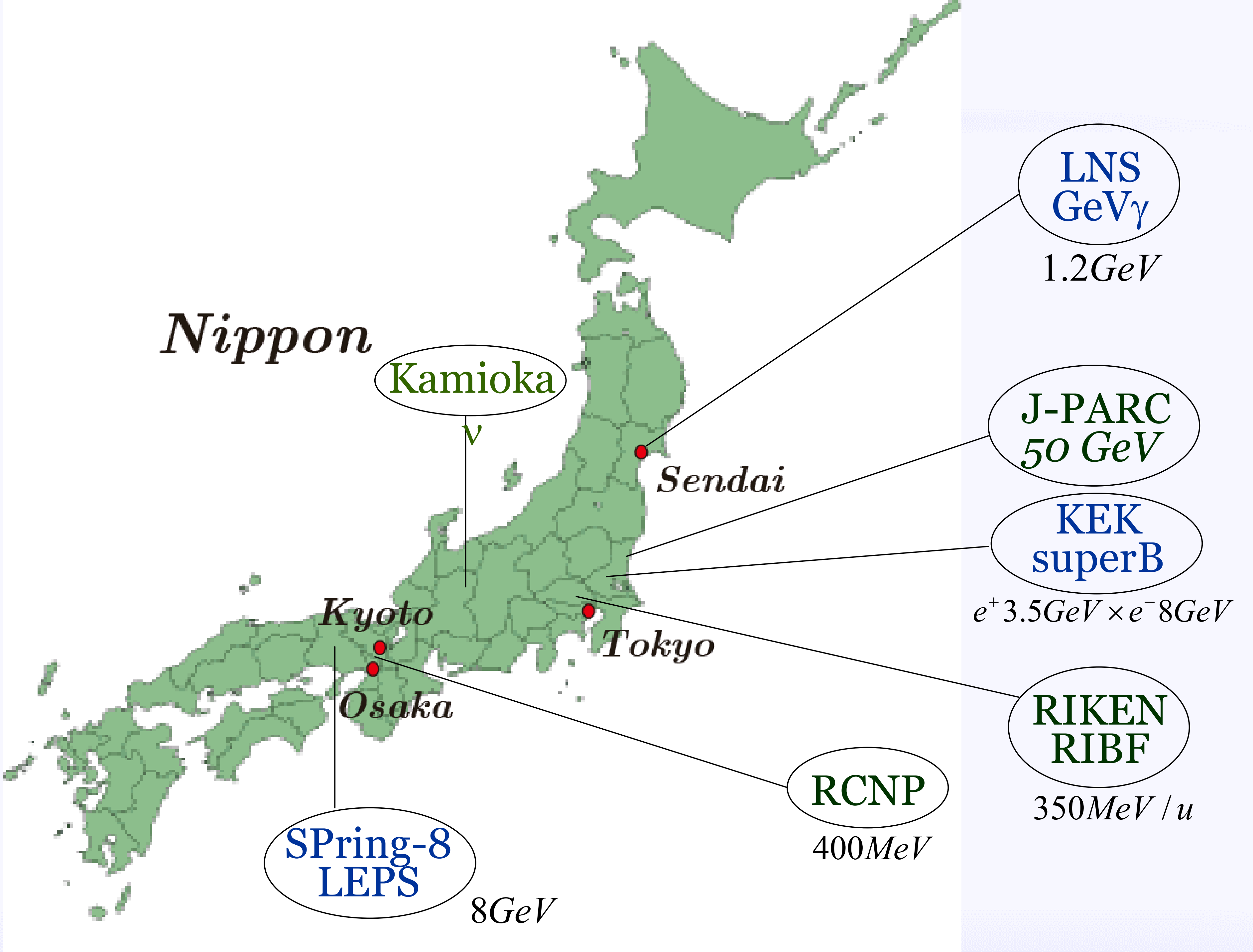
Data taking started in autumn, 2008.



π^0	~2M events/day
η	~40k events/day

Fast DAQ system

efficiency of 76%
trigger rate: 2kHz
for the data size of
2.6kB/event


Nippon
LNS GeVγ
1.2GeV
Kamioka
ν
J-PARC 50 GeV
Sendai
KEK superB
e+3.5GeV × e−8GeV
Kyoto
Tokyo
Osaka
RIKEN RIBF
350MeV / u
RCNP
400MeV
SPring-8 LEPS
8GeV